Directed Energy

A Look to the Future

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It is incumbent upon every Air Force officer to support the current fight; however, senior leaders, especially those on the Air Staff, must prepare the Air Force to take the fight into the next decade and even the next half century. As technologies mature, we continually assess their impact and enable our forces to embrace the capabilities they offer, all the while readying ourselves for any vulnerability they create when exploited by our foes. At a minimum, directed energy (DE) will be a game changer, but it has the potential to create a revolution in military affairs. In anticipation of what I believe will prove an integral part of our force-application capabilities within 10–20 years, I wish to arm the readers of this journal with some important information. To begin, I outline where DE technologies are today, followed by a review of four programs critical to the Air Force: the Airborne Laser (ABL), the Advanced Tactical Laser (ATL), the Counter-Electronics High Power Microwave Advanced Missile Project (CHAMP), and the Active Denial System (ADS). I then review the vulnerabilities we

USAF photo

Airborne Laser

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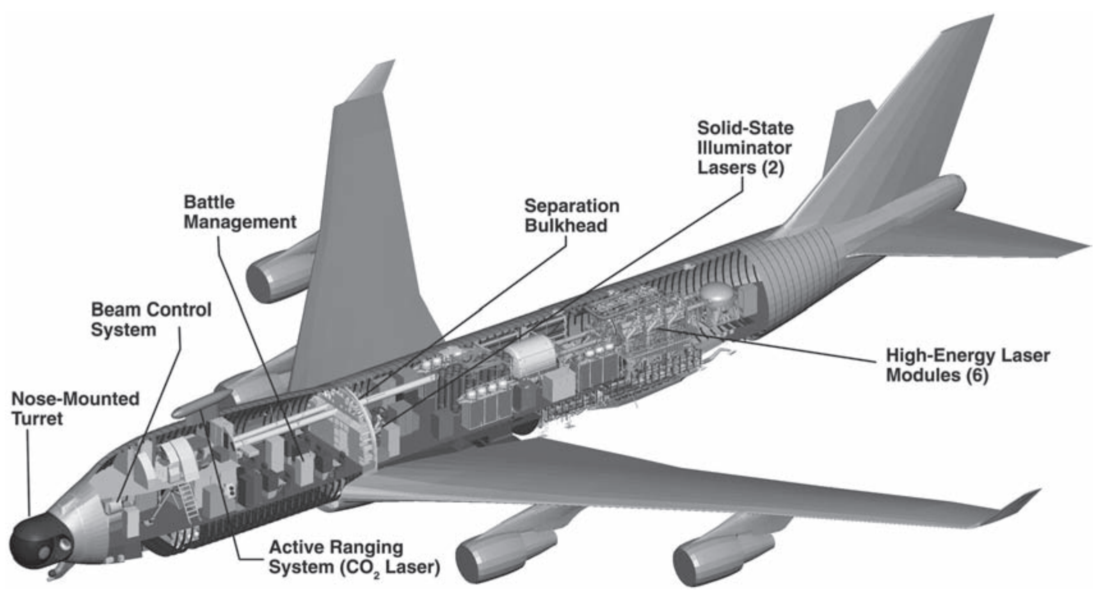
face and discuss the challenges to fielding these systems. I conclude by addressing the efforts we are undertaking as an Air Force to prepare for the arrival of DE weapons in air, space, and cyberspace.

Current and Near-Term Technology

DE weapons have been on the horizon for several decades. In 1960 Theodore Maiman invented the first laser, which used a synthetic ruby crystal and had an output power of only a few milliwatts. By the 1970s, laser power had reached the megawatt level, an advance that, in the early 1980s, led to development of the successful Airborne Laser Lab—a gas-dynamic laser mounted in a modified version of a KC-135 used for flight testing. Extensively modified by the Air Force Weapons Laboratory at Kirtland AFB, New Mexico, the NKC-135A destroyed five AIM-9 Sidewinder air-to-air missiles and a Navy BQM-34A target drone during an experiment. More recently, advances in chemical lasers, optics, and beam control have led to both the ABL and ATL.

The ABL, a chemical laser mounted inside a Boeing 747, provides defense against tactical ballistic missiles such as the Scud.[1] Started by the Air Force in 1996, the program transferred to the Missile Defense Agency in 2001. Boeing serves as the integration contractor, Northrop Grumman furnishes the chemical oxygen iodine laser (COIL), and Lockheed Martin has responsibility for the nose turret and fire-control system. To date, the ABL has demonstrated the ability to track and illuminate targets and has fired the laser during ground tests. Live-fire tests against representative threats from tactical ballistic missiles are scheduled to begin in late calendar year 2009.



Boeing 747-400F Airborne Laser

Considered by many individuals to be the most complex military weapon system ever developed, the ABL is designed to destroy ballistic missiles during their boost phase, when the laser's energy can weaken the missile structure enough to cause it to fail catastrophically due to the stresses of flight. The weapon system includes an infrared surveillance system to detect launch, a fast-tracking system and target-illumination laser for accurate tracking, and a beacon-illumination laser, which generates information to an adaptive optics system that precompensates the high-energy COIL beam and allows the atmosphere to focus the laser energy on target. Although each piece of this kill chain presents sophisticated challenges, the integration of all these systems multiplies the complexity. Regardless, the program has thus far addressed the challenges and remains on schedule to offer a game-changing capability to the nation.

Consider how this capability will affect future engagements. The current program will allow us to negate short, medium, and intercontinental ballistic missiles, thus significantly improving force protection, enabling us to operate from closer bases, and enhancing the positioning of naval forces. Future developmental spirals will give the ABL more laser power and better range. Combining these enhancements with relay mirrors may enable very-long-range, over-the-horizon engagement of enemy aircraft or cruise missiles.[2] We can even envision a number of ancillary missions for the ABL, perhaps including one for defensive counterair. These capabilities are not just dreams. The ABL has ground-tested the laser and demonstrated the tracking system on surrogate targets. It remains on schedule for live fire this calendar year.

Another possible airborne application of high-energy lasers, the ATL program began in 2001 as an Advanced Concept Technology Demonstration (ACTD) sponsored by Special Operations Command; it subsequently transferred to the Air Force in 2008. The ATL has demonstrated the optics and tracking system in low-power flight tests, fired the high-energy laser on the ground, and (at the time of this writing) conducted two high-energy flight tests and target engagements. As noted in a recent Scientific Advisory Board study, the ATL will be able to engage targets at the speed of light with unprecedented precision and very little or no collateral damage.[3] The current ATL incorporates a COIL into a C-130, filling the cargo space of the test aircraft because of the laser's very large size. However, when high-energy, solid-state lasers mature, one of these smaller, lighter-weight devices will fit within one of the three weapons stations in an AC-130. The combination of the laser's precision and the kinetics of the aircraft's 105 mm howitzers will give Air Force Special Operations Command a formidable force-application capability.

Laser technology is not the only area in which DE weapons have made significant advances. Radio frequency (RF) DE, most commonly high-power microwaves (HPM), has also demonstrated unique capabilities in nonlethal engagement. Over the next three years, the CHAMP ACTD seeks to demonstrate HPM weapons capable of disrupting any military system containing electronics by disabling or destroying the electronics components. To quote the father of HPM research, Dr. Bill Baker of the Air Force Research Lab, "The smarter the weapon, the dumber [counterelectronics] will make them"—all this with no effect on people or structures.[4] This nonlethal capability not only will offer the president and secretary of defense a measured means to engage adversaries but also will give military leaders reprogrammable weapon systems with adjustable effects.

To employ the awesome capability of HPM weapons properly, we must begin preparing now. If all goes according to plan, CHAMP will become a program of record in 2014. If we wish to use it effectively, we must (1) develop the intelligence structure necessary to target the weapon (joint munitions effectiveness manuals for nonlethal engagement),[5] (2) ensure that we have an appropriate delivery system in the inventory (current or future standoff weapons,

USAF photo

COIL-carrying C-130 (Note the elongated nose, which housed enhanced radar for controlling a remotely piloted vehicle on a previous mission.)

unmanned aircraft systems, etc.), (3) develop effective battle damage assessment (BDA), and (4) train our combatant commanders to use these tools productively. We must start developing this groundwork today to guarantee effective use of these game-changing technologies tomorrow.

Another RF system under development, the ADS, projects a gigahertz RF beam that rapidly heats the surface layer of a person's skin, producing a nonlethal effect described as "opening an oven door."[6] The ADS presents our forces with a very-long-range "water cannon" for dispelling crowds or determining intent. We can deploy this system in a stationary application today, and the Joint Non-Lethal Weapons Directorate is currently developing a mobile application.

Vulnerabilities Associated with Directed Energy

We are not alone in developing DE capabilities. Potential adversaries are making significant investments in DE, and we are witnessing the development and commercial marketing of high-energy lasers for numerous very-short-range (requiring low beam quality) industrial applications.[7] Founded, owned, and operated by Russian expatriates, IPG Photonics—a US-based world leader in high-power fiber lasers—currently markets a 50-kilowatt fiber laser with over 25 percent efficiency.[8] In comparison, the Department of Defense's Joint High Power Solid State Laser program demonstrated a 100-kilowatt-class laser with good beam quality (militarily significant range) earlier this year with an efficiency of 15–20 percent. To be fair, this laser will have beam quality (a measure of how tightly a beam can be focused) far superior to that of the IPG industrial laser.

Additionally, the French, British, and Germans also have DE programs. For example, the Diehl company of Germany is marketing HPM devices capable of generating a counterelectronics pulse with a range of 10 or more meters. Clearly, DE capabilities are being developed around the globe. Preparing for these threats is critical.

Recently, the DE Task Force concluded its Directed Energy Net Assessment (DENA), a yearlong study that leveraged the expertise at the National Air and Space Intelligence Center, Air Combat Command, Army Acquisition Corps, Air Force Research Laboratory, and Air Staff to investigate vulnerabilities we will face in the next decade. Us-

ing two scenarios—a major contingency operation and an expeditionary operation—the DENA assessed threats from a near-peer nation and from a less sophisticated adversary using commercial off-the-shelf capabilities. During the past year, the DENA completed detailed scenario development, including mission-level objectives, a rigorous intelligence evaluation and threat lay-down, and technical analysis of DE effects on our systems. This information was then combined with modeling and simulation efforts and war-gamed by the USAF Weapons School to determine the impact on our operations. Finally, the study prioritized the vulnerabilities and recommended tactics, techniques, and procedures to mitigate these vulnerabilities. For vulnerabilities that require material solutions, the report provided concrete recommendations to help drive our research and investments in hardening our systems and protecting our forces.

Future Directions

DE capabilities are still in the laboratory; however, within this unclassified forum, I hope to provide *Air and Space Power Journal*'s readers with a sense of urgency. On the threat side, the Chinese have a very active DE research program; Russian companies lead the world in fiber lasers; and a German company markets a counterelectronics suitcase bomb. On the developmental side, the ATL has successfully targeted, tracked, and fired on several ground targets; the ABL is scheduled to fire against surrogate targets in late calendar year 2009; we are beginning the CHAMP ACTD; and the ADS system is preparing for deployment now. DE weapons are truly just around the corner.

To prepare for the arrival of DE capability and threats, we have much to do. As mentioned above, we are conducting a DENA of our vulnerabilities. But our work will not stop there. The DENA will serve as a launching point for several efforts. First, it will identify areas needing more research and investigation. Although the DENA is not meant to be an all-inclusive study, it will remove our blind spots and point to "what we don't know." Second, we will use the modeling and simulation results of the DENA to improve our war-gaming models and to influence the Capabilities Review and Risk Assessment process, thereby further defining our capabilities and vulnerabilities. Moreover, it will give us tools for assessing new tactics, techniques, and procedures used to employ or defeat DE weapons. Third, the DENA will drive our investments in hardening. Despite the Air Force's ever-present budget constraints, prioritizing our vulnerabilities will allow us to research and develop hardening strategies for our most critical vulnerabilities first. Finally, it will provide the basis for developing requirements. The DENA will equip us with the technical evaluation and critical assessment we need for solid requirements—the foundation of our acquisition process. Though not the end of vulnerability identification and mitigation, the DENA is a powerful start.

The Air Force must learn to employ DE weapons. We know kinetics; we know how to model the effects; we have detailed target sets and the joint munitions effectiveness manuals; we have detailed intel to support targeting; and we have sophisticated BDA techniques. To support a new era of weaponry, we must examine the entire kill chain and assess the required changes. To target the weapon effectively, we must change intel collection procedures to support new engagement methods (e.g., counterelectronics). With kinetic weapons, we developed methods to increase the yield (all the way to nuclear) and decrease the yield (e.g., small diameter bomb) to obtain the desired effect. DE weapons will allow an instantaneously variable "yield" (reprogrammable in flight). To support this capability fully, the combatant commander must have detailed understanding of the weapon's effects. This information is supported by researching those effects as well as modeling and simulating them. We have begun these efforts, but they remain in their infancy. Moving down the kill chain, we see that delivery methods in-

clude those that are manned and unmanned, expendable and recoverable, reprogrammable, terrain following, and stealthy, among others. When modifying existing platforms or developing new ones, we must take into consideration the unique aspects of employing DE weapons (incident angle with target, antenna size/location, optics, atmospheric effects, etc.). Finally, these weapons can be much more precise with variable lethality and thus significantly reduce collateral damage—a benefit in most cases. But BDA is much more difficult, requiring that we think outside the box since it doesn't involve just imagery. For example, we could conceive of cyber forces supporting BDA for a counter-electronics weapon. Fellow Airmen, welcome to the twenty-first century. We have much to do to prepare for the advent of DE in the battlespace.

Game-changing technologies such as this will affect the Air Force across the constructs of doctrine, organization, training, materiel, leadership and education, personnel, and facilities (DOTMLPF) (see table). Concepts of operations (CONOPS) and concepts of employment (CONEMPS) will continue to mature as we gain experience with DE systems and threats; however, DE policy is critical to the fielding of weapons. The only existing policy with respect to DE weapons is a prohibition on using lasers to inflict blindness.[9] As more capable weapons are fielded, we will develop policy individually for weapons, based on the effects. Nevertheless, this work should begin now, during the tech-demonstration phase, so that the General Council has the required data to support and develop coherent policy. Additionally, training and education will play a significant part in developing war fighters who effectively employ as well as self-protect in the DE battlespace. Of course, new material solutions will affect personnel and facilities. Most importantly, though, it is incumbent upon Air Force leadership to fully understand the nature of these capabilities and the maturity of this technology so we can enable our forces to employ DE weapons and protect our people from their effects.

Table. DOTMLPF considerations for a DE Air Force

DOTMLPF	*Considerations*
Doctrine	• CONOPS • CONEMPS • Policy
Organization	• DE intelligence • DE concept exploitation—war gaming
Training	• New employment methods • Advanced weaponry • DE self-protection
Materiel	• Weapons • Platforms • Sensor/system hardening
Leadership and Education	• Weapons options • Weapons employment • Advanced technologies
Personnel	• DE weapons experts • DE weapons maintainers • Logistics support structure
Facilities	• Test and evaluation infrastructure • High-energy-laser maintenance facilities • HPM weapons storage

Conclusion

DE weapons will be the most significant technological change that most of us see in our military careers. The technology has been advancing for many years, but never before have there been so many key technology demonstrations: ABL, ATL, CHAMP, and ADS. I am convinced that, given the proper investment, we can develop a fieldable DE capability within the next five years. We have much to do while the scientists and engineers work: assessing vulnerability, developing CONOPS, and assessing our readiness to use these weapons effectively across the DOTMLPF construct. With such promising capabilities on the horizon, I hope you will join us in preparing the Air Force for the future fight. ✪

Notes

1. The ABL combines the power of six chemical oxygen iodine lasers to produce a megawatt-class weapon system.

2. The Tactical Relay Mirror System is an Air Force Research Laboratory program designed to demonstrate the ability to extend the range and accuracy of high-energy lasers by means of airborne mirrors or relay systems (active mirrors).

3. Dr. Hsiao-hua K. Burke et al., "Airborne Tactical Laser (ATL) Feasibility for Gunship Operations," Air Force Scientific Advisory Board Study (Washington, DC: Headquarters US Air Force, Scientific Advisory Board, 2008).

4. Douglas Beason, *The E-Bomb: How America's New Directed Energy Weapons Will Change the Way Future Wars Will Be Fought* (Cambridge, MA: Da Capo Press / Perseus Publishing Group, 2005), 214.

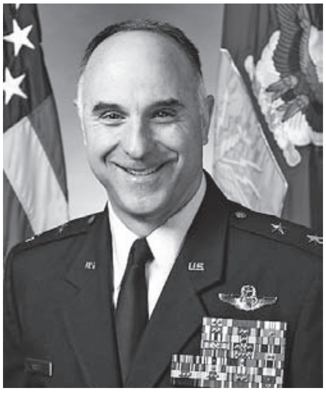
5. A separate group of these manuals is being developed for nonkinetic DE and electronic-warfare effects.

6. In over 11,000 tests, the system has not caused a single case of long-term damage; in most cases (99.9 percent), the symptoms vanish as soon as the individual flees from the beam.

7. Although industrial lasers can produce significant power, their potential military effective range is relatively short because the beams are optimized for very-short-range (a couple of inches to a foot or two) welding, cutting, and so forth.

8. With headquarters in Oxford, MA, IPG has manufacturing facilities in the United States, Germany, Russia, and Italy, as well as regional sales offices in Japan, Korea, India, and the United Kingdom.

9. In October 1995, the United States joined 43 other nations in approving a ban on blinding laser weapons. The international protocol was developed in Vienna, Austria, during a review of the Conventional Weapons Convention, also known as the Inhumane Weapons Convention.



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